A Simulation Study of Project Management and Collaborative Information Technologies

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ABSTRACT

Communication plans are intrinsic to project management. However, the time and cost effects of communication plan choices have largely been overlooked. Herein, we study the impact of three types of communications plans that implement collaborative information technologies (CITs) (i.e., asynchronous, synchronous and both) on the key project metrics of communication cost and project schedule performance across projects of different complexity. We use simulation and virtual experiments to gather data for a two-way ANOVA analysis. Our results indicate that the communication cost and schedule performance significantly differ based on the communication plan choice of CITs and complexity. Also, some communication plans carry more cost or schedule risk (i.e., variation) across project complexity than others. As such, project managers should strategically consider the nature of the project and the choice of CITs as important inputs when generating a communication plan.

Keywords

Project management, communication plans, collaborative information technologies, simulation, virtual experiments

INTRODUCTION

Project management entails the development of strategic communication plans that often involve the assignment of collaborative information technologies (CITs) at the beginning of the project (e.g., Kerzner, 2001; Schwalbe, 2010). While research has examined the success with which teams produce outputs when collaborating via information technologies (e.g., Easley, Devaraj and Crant, 2003), little is known about using information technologies as per the communication plan. Team members apply their time to collaborate via prescribed information technologies and their time translates into project costs. Recent research has acknowledged that there is a tradeoff between the amount of team communication and the cost of the project thereby showing communication plans are important for limiting the project costs (Lin, Qian, Cui and Miao, 2010). In our research we quantify the communication costs associated with using CITs during the project.

Past researchers suggest, however, that the complexity of the project may impact the information that needs to be transmitted (Patrashkova and McComb, 2004). As such, complex projects that do not have clear solutions may require more information content to be exchanged than less complex projects. Moreover, depending on the difficulty or complexity of the project, then information may be better sent across certain types of media. That is, richer communication media might be needed when sending information that requires more discussion, clarification, and agreement (Chidambaram and Jones, 1993and). The richness of media is due to the number of channels available to send information cues and therefore, the amount of information that is conveyed at one time (Daft and Lengel, 1986). If the right type of media is not paired with the content of the message, then more communication, and therefore more time, is needed to get the message across to team members and to ensure they understand the message, ask questions and get the necessary clarifications. Thus, we seek to understand the communication costs and project schedule consequences across high, medium, and low project complexities and of communication plans requiring the use of different CITs.

The research provided in this paper contributes to project management research and the way project managers will make strategic decisions about the use of CITs as identified in communication plans. We ascertain our findings using simulation and virtual experiments. The simulation model generates a project over its lifecycle and the information requirements of each lifecycle phase. The simulation is adapted from the model used in the research by Patrashkova and McComb (2004). We then conduct virtual experiments by generating projects with different complexities and with different CIT media selection based on communication plan decisions. We apply a cost feature to the results and answer research questions about the costs and schedule performance of different communication plans. The research questions of interest are advanced in the next section.

Communication Plans

Effective project communication is needed to ensure that team members get the right information to the right person at the right time and in a cost-effective manner. Indeed, the proper communication may be vital to the success of the project and the organization as a whole (Schwalbe, 2010). Hence, organizations need to take a conscientious approach to setting communication policies. Some organizations already do. For example, the telecommunication organization Atos SA implemented a "zero email" policy to help employees reduce their wasted time (Colchester and Amiel, 2011). Other plans direct the way members will communicate with each other, customers, stakeholders, etc. as seen in the Communications Management Plan for Interoperability Montana (Northrup Grumman Corporation, 2007) and the Project Communication Handbook for the California Department of Transportation (Caltrans Office of Project Management Process Improvement, 2007). In this study we want to highlight the waste that might be hiding in communication plans through two metrics. First, we examine the communication costs of different communication plans. These costs reflect the unit cost of using different types of collaborative information technologies (CITs). Because different CITs may take longer or shorter interaction times, then costs may differ across CITs as well. Second, we evaluate the project schedule performance which reflects whether the project is ahead of schedule, on-time, or delayed, in comparison to the estimated project duration determined at the beginning of the project.

There are several media alternatives for communication that a manager must consider when building a communication plan. Moreover, with the proliferation of information technologies, managers have many CIT alternatives to choose from when making the communication plan. Managers may select a mix of information technologies for synchronous or asynchronous collaboration. Synchronous collaboration can occur via technologies that allow people to interact with each other simultaneously (e.g., Baker, 2002; Drury and Williams, 2002), such as via voice over internet protocol (VOIP), phone calls, video-conferencing, etc. Asynchronous collaboration is enabled via information technologies that manage interactions across temporal boundaries (e.g., Levitt, Cohen, Kunz, Christiansen and Jin, 1994; Ocker and Yaverbaum, 1999), such as text messengers, email, or discussion boards. In this research, we consider three types of communication plans to provide us with baseline information about the impact of strategic communication plan decisions. The communication plans of interest include plans that require communication to occur via synchronous CITs only, asynchronous CITs only, or a combination of CITs.

Researchers suggest that project team members spend different amounts of time using different CITs (LaToza, Venolia, and DeLine, 2006). This may be because CITs are differentially efficient in exchanging a piece of information depending on its content (Chidambaram and Jones, 1993), which may directly affect the member's time spent on exchanging information. Email, an asynchronous medium, would be a quick and effective way to communicate simple and small information since composing text may not take too much time. Using VOIP, a synchronous medium, might be a more effective way to communicate ambiguous information, however, it may add up to more overall time because of the preparation needed to organize the call and prime for a more fluid conversation about content topics. Thus, the choice of CITs (i.e., asynchronous or synchronous) is expected to have an effect on the communication cost accrued from members outlay of time efforts in preparing and sending messages during the project.

As well, the efficiency of the medium in sending the necessary content may affect the overall length of the project. As media richness literature suggests, media limits the amount of information content that is communicated between sender and receiver (Daft and Lengel, 1986). Synchronous media are notably more effective at sending information content than asynchronous media (Chidambaram and Jones, 1993) and therefore more information content may be sent when routed through synchronous media than through asynchronous media. Given that projects have a total amount of information content that needs to be exchanged during the project; the use of different CITs may affect the ability of the project team in meeting schedule requirements. Moreover, the amount of information content required may depend on the project complexity. For example, a highly complex project such as new product development may require more information content to be exchanged than a less complex project such as an incremental improvement in product design. To understand the communication costs and project schedule consequences of different communication plans requiring synchronous CITs and asynchronous CITs across projects of different complexities our research questions are:

> *Research Question 1: How do project communication costs differ based on communication plans that use CITs differentially (i.e., synchronous CITs only, asynchronous CITs only, or a combination of CITs) across projects of different complexity?*
>
> *Research Question 2: How do project schedule performances differ based on communication plans that use CITs differentially (i.e., synchronous CITs only, asynchronous CITs only, or a combination of CITs) across projects of different complexity?*

SIMULATION AND VIRTUAL EXPERIMENTS

Figure 1 represents the two part process of simulation and virtual experiments used in this research. Part 1 shows the different steps of the simulation model and attributes generated at each step of the model that we adapted from the research by Patrashkova and McComb (2004). This simulation is coded to restrict communication exchanges to be only between the team members that need information and members that have the information. By limiting the exchange between relevant team members we eliminate risk of inflating the communication cost due to the involvement of non-relevant team members, which is an important managerial concern for large complex projects. We validate our simulation model by generating projects and comparing the actual project schedule to the estimated project schedule. This is the same validation technique used in the paper by Patrashkova and McComb (2004). Our t-test shows that the actual project schedules and the estimated project schedules were not significantly different at an alpha of 0.05 (n = 35, t-stat = 0.13, p = 0.89) which indicates that the simulation generates projects that finish on time. Thus, with the valid simulation model we move to Part 2 where we apply constraints to gather data about costs and schedule performance of communication plans under different complexity and media selection.

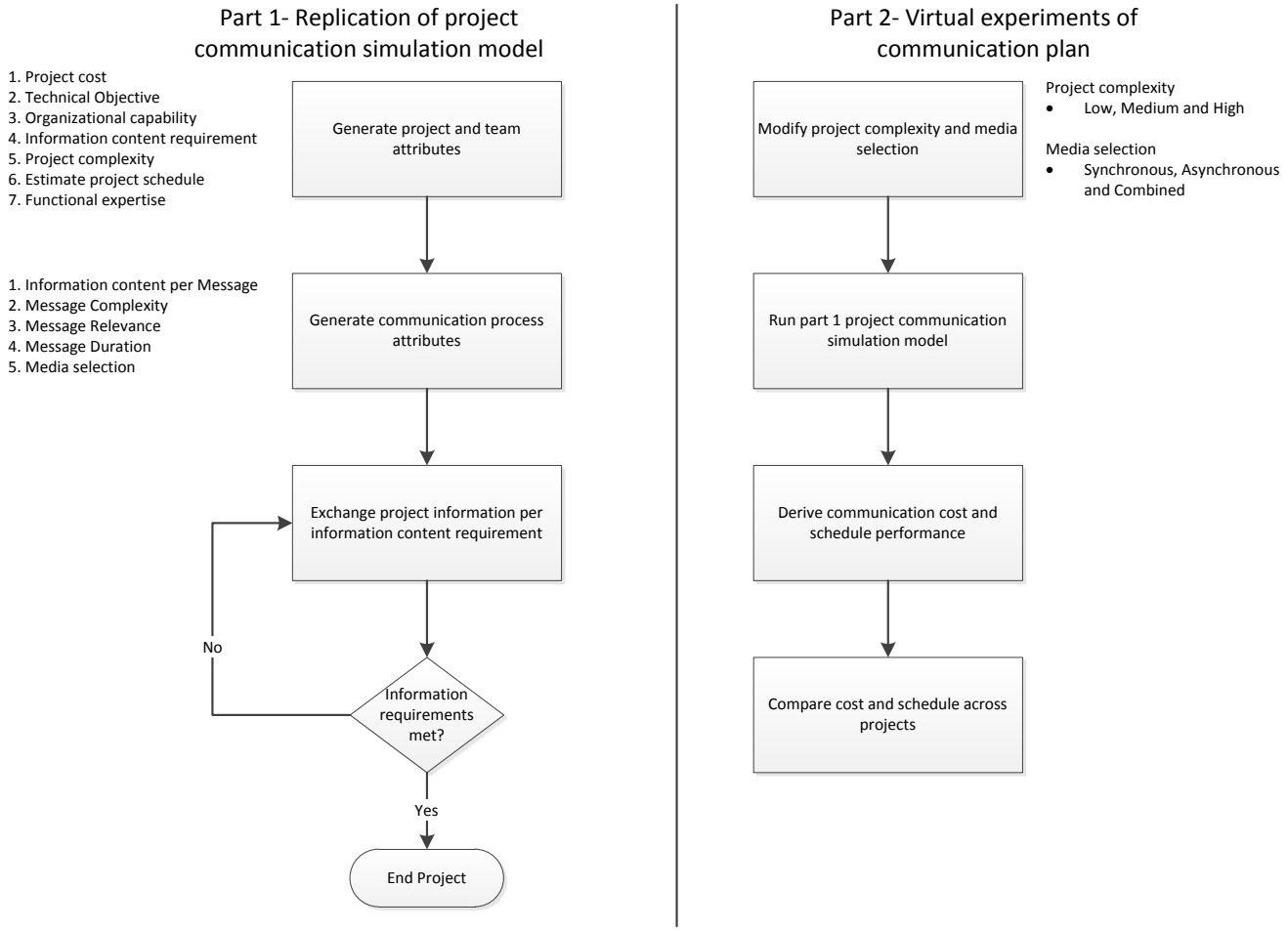

Figure 1. Simulation and Experiment Flow Chart

As shown in Figure 1, Part 2 adds constraints about project complexities and media selection for a 3 x 3 experimental design. Herein, the three different project complexities we use are low complexity, medium complexity, and high complexity. The project complexities influence the total information content requirement of the project and thereby affect the amount of information content that needs to be exchanged to complete the project. The media selection constraints represent three

different communication plans consisting of all synchronous, all asynchronous, or a mix of CITs. The range of values used for attributes during simulation and experiments are shown in the Appendix.

Each experimental condition was imposed for a sample size of 35 projects. For each project we capture five outcomes. **Total communication costs** are calculated by adding the costs of synchronous communication and costs of asynchronous communication. Cost of synchronous (asynchronous) communication is calculated by taking the product of number of synchronous (asynchronous) messages and cost of exchanging a synchronous (asynchronous) message. We consider the cost of a synchronous message to be 3 times that of the asynchronous message, which represents the differential use of member's time on these types of media ascertained from LaToza et al. (2006). The **number of messages** is the total number of messages exchanged to meet the information content requirements of the project. The message **content** refers to the amount of information exchanged per message. Notably, synchronous CITs are assumed to be able to transfer up to twice as much information content as asynchronous CITs. The **estimated schedule** is the estimated duration required to exchange messages (content) to meet the total content requirement. The **actual schedule** is the actual duration required to exchange messages (content) via the selected media in order to meet the total content requirement of the project. These outcomes allow us to calculate the average cost/message, average content/message, and the project schedule performance which is the critical ratio of the estimated duration to the actual duration. Table 1 summarizes the data gathered from the experiments.

Communication Plan for CIT usage	Total Communication Cost (units)	Average Cost/ Message	Average Content/ Message	Number of Messages	Estimated schedule (weeks)	Actual schedule (weeks)
Low Complexity Project						
Synchronous	96239.94	77.41	6.50	1243.22	31.31	16.42
Asynchronous	254357.00	77.03	2.50	3302.00	30.51	43.26
Combined	150953.00	76.98	4.50	1960.85	31.40	25.74
Medium Complexity Project						
Synchronous	213042.00	77.08	6.50	2763.88	55.45	36.22
Asynchronous	592124.00	77.17	2.50	7673.00	60.65	100.80
Combined	311171.00	77.01	4.50	4040.60	56.00	53.00
High Complexity Project						
Synchronous	354446.00	77.13	6.50	4595.25	83.08	60.48
Asynchronous	935461.00	76.97	2.50	12153.94	82.25	159.48
Combined	508902.00	77.08	4.50	6602.20	80.80	86.71

Table 1. Data Summary Table

To answer Research Question 1 of whether project communication costs differ based on the communication plans that include synchronous CITs only, asynchronous CITs only, or a combination of CIT types across projects of different complexity we conducted a Two-Way ANOVA to compare total communication costs across complexity and CIT use. The results indicate that the interaction of complexity and communication plan was significant for project communication costs (interaction test: $F\text{-}stat = 75.66$, $p\text{-}value < 0.01$). As such, project communication differed in total costs depending on the complexity of the project as well as the communication plan requirements (i.e., synchronous only, asynchronous only, combined).

To better understand these effects, Figure 2 graphs the average total communication costs over different complexities and CITs. As shown in the graph the cost of low complexity projects show the lowest total communication cost across CITs while costs of high complexity projects have the highest total communication costs. Moreover, communication costs for projects across different complexities using only synchronous CITs shows the least variation (σ^2 = 2,237,375.90), while the communication costs for projects across different complexities using only asynchronous CITs shows the most variation (σ^2 =

15,049,865.60). The variation of communication costs for projects using a combination of CITs falls between projects using only one type of CIT (σ^2 = 4,249,911.50). Since variation, or the spread of the outcomes, may represent risk in project outcomes, our results suggest that using synchronous CITs alone may be less risky of being a costly endeavor than using asynchronous or a combination of CITs.

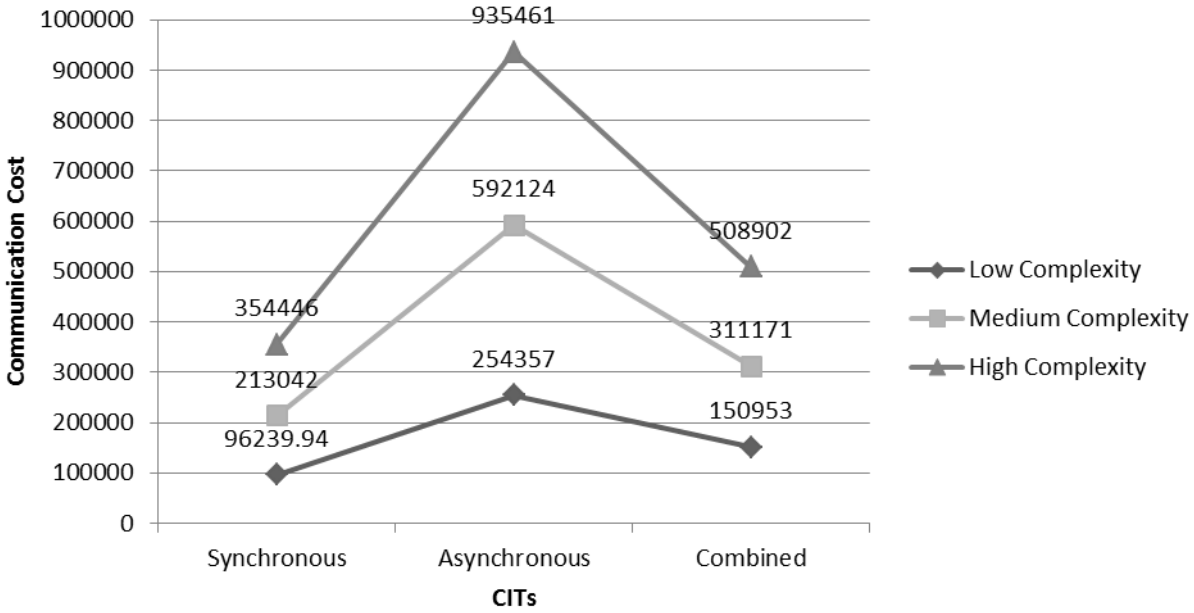

Figure 2. Communication Cost over Different Complexities and CITs

In Research Question 2 we asked whether project schedule performance differs based on communication plans that use CITs differentially (i.e., synchronous CITs only, asynchronous CITs, only, or a combination of CITs) across projects of different complexity. The project schedule performance is calculated as the critical ratio of estimated schedule and actual completion times (i.e. Project Schedule Performance = (Estimated Schedule) / (Actual Schedule)). This critical ratio is comparable to the critical ratio used in project management to determine the schedule adherence of a project (Heizer and Render, 2011). As such, values greater than 1 mean that the project is completed ahead of the schedule, a value of 1 means the project is completed on schedule, values less than 1 mean the project is delayed. We conducted a Two-Way ANOVA to compare project schedule performance across projects with different complexities using different communication plans. We found that the interaction of complexity and communication plans was significant (interaction test: *F-stat* = 7.42, *p-value* < 0.01). As such, project schedules differ in on-time performance depending on the complexity of the project as well as the communication plan requirements (i.e., synchronous only, asynchronous only, combined).

Figure 3 plots the schedule performance ratios over different complexities and CITs. As shown in the graph, the schedule adherence of the high complexity projects seems flat, or more similar, across CIT usage than projects of other complexities. The critical ratio for high complexity projects indicates a delay in the project when the communication plan calls for asynchronous CITs or combined use of CITs. Medium complexity projects have larger differences in schedule adherence across CIT usage than high complexity projects, yet the use of asynchronous CITs or combined use of CITs results in projects being closer to on-schedule (i.e., having a critical ratio closer to 1). Low complexity projects, with large differences in schedule adherence across CIT usage, are reported to be ahead of schedule when the communication plan calls for synchronous CITs or combined use of CITs. Thus, for certain complexities, the use of individual or combined CITs matters for on-time or early project completion.

Further the plot shows that projects with any complexity using only synchronous CITs, on average, complete ahead of the schedule. Projects with any complexity using only asynchronous CITs, on average, do not complete on schedule. Looking at the variation, or spread of the schedule adherence across CITs shows that the use of synchronous CITs only has the most variation (σ^2 = 1.00) as compared to the use of asynchronous CITs only (σ^2 = 0.08) or in combination (σ^2 = 0.12). Therefore,

communication plans that require only synchronous CITs carry the most risk in schedule adherence. Implications are presented in the discussion.

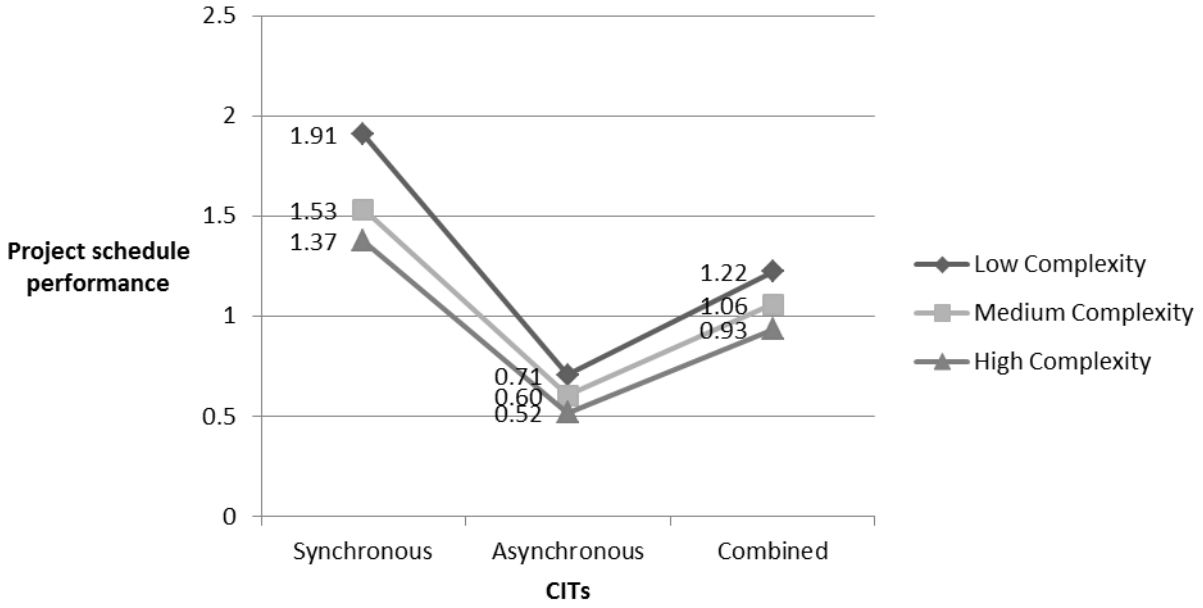

Figure 3. Project Schedule Performance over Different Complexities and CITs

DISCUSSION

The research conducted herein examined the impact of communication plan choices, specifically the use of synchronous CITs, asynchronous CITs, or a combination of CITs, on cost and schedule outcomes. Further, we sought to understand the impact of plan choices across projects with different levels of complexity. Our results showed that the choice of CITs in the project execution for a given project complexity impacts the cost of communication and the ability of the project to complete on schedule. Research and practical implications are discussed below.

Our research shows that total communication costs were different for projects with different complexities and communication plans and that the synchronous CITs are the cheapest option to implement, assuming only entities having information and entities needing the information are involved in the communication. This finding is interesting given that our data shows that the cost per message appears to be the same for CITs across all project complexities. The reason for the difference in communication costs between asynchronous CIT and synchronous CIT usage, with the lowest costs going to synchronous usage, is explained by the number of messages required to communicate the information. Indeed, our results show that when compared to synchronous CITs, asynchronous CITs require more messages to communicate similar amounts of information that were determined by project complexity. More total messages in the asynchronous CIT plan translate into more time spent communicating and that drives up the cost. So using asynchronous CITs may be deceiving when only convenience or the cost per message is considered. Rather, less time and, therefore, money may be spent by making the effort to arrange communication via synchronous CITs. An example of how synchronous CITs may reduce the time and, therefore, cost is to consider a team meeting held via a synchronous CIT such as a video-conference system. The meeting may effectively help all members get "on the same page" that replaces the extraneous routing of emails that takes time for members to read and respond in kind. Thus, project managers may want to structure the communication plan to utilize synchronous CITs as much as possible in order to mitigate costs due to communicating time.

Another finding from our research is that the project schedule performance is impacted by the choice of CITs and the project complexity. We did find that the combined use of synchronous and asynchronous CITs during the project resulted in the project completing approximately on time. Moreover, the use of only synchronous CITs resulted in projects completing ahead of the schedule while the use of only asynchronous CITs resulted in projects slipping the schedule. The reason for the schedule performance may once again be due to the deceptive efficiency of asynchronous media. That is, while asynchronous media required less time than synchronous media, less content could be sent. Therefore, more messages, and in turn, more time added up. The cumulative duration of all asynchronous messages led to delayed projects. To consider how this might

occur we suggest that the time spent brainstorming through a VOIP call or instant chat may be more time efficient because it allows members to bounce ideas off of one another simultaneously and gain immediate feedback. When using asynchronous technology such as email the team may be delayed during the back and forth that passes idea by idea and therefore slows down the creative process. If not enough content is exchanged in the scheduled time, then a delay may slow down the project as a whole. As such, it is important for project managers to realize the content requirements of the project and plan accordingly so that the project stays on schedule. Further, if the project is evaluated to be behind schedule then the project manager might have the team communicate via synchronous CITs to bring it back on schedule.

A final insight from our results comes from considering the variation in outcomes. Since variation is an inherent measure of risk then we draw some other implications for project managers. When the communication plan calls for only asynchronous CITs then the cost of communication shows the most variation across projects complexities; yet, this plan also shows the least variation in the project schedule performance across projects complexities. Alternatively, the communication plan calling for only synchronous CITs results in the cost of communication having the least variation across projects complexities while the most variation in schedule performance across project complexities. So there is a tradeoff in carrying risk that the project manager has to make. Depending on the complexity of the project, its information requirements, and available CITs, project managers should be conscientious of their risk tradeoff before selecting a communication plan.

Limitations and Opportunities for Future Research

The research conducted herein elucidates the cost of collaboration over different types of information technologies when that collaboration is directed by communication plans. While insights were gained from our findings, this study has certain limitations that offer opportunities for future research in this area. First, our findings are limited due to the methodology employed to capture projects, team collaboration, and media use. That is, in our model project complexity is controlled. The possible values for project complexity range from 1 to 9. Low, medium and high complexity projects are assigned project complexity between 1 and 3, 4 and 6, and 7 and 9 respectively. The content required to be shared between the team members is directly proportional to the complexity of the project. However, this may not always be so; a complex project may exist where little content is required to be exchanged (e.g., airplane crew situations, medical surgeries, rescue teams). Thus, while our simulation was based on a validated model from the literature (Patrashkova and McComb, 2004), which enabled us to study scenarios that would be time and cost prohibitive in a laboratory or real-world setting, future researchers are encouraged to capture the time and costs incurred from collaborating according to CITs assigned in communication plans.

Second, in this study we considered communication plans that require synchronous CITs or asynchronous CITs. As such, our virtual experiments are looking at the extreme end of the communication band. We used email messages (highly asynchronous) and video-conferencing communication (highly synchronous) as representative types of CITs. All other types of communication which fall between the extremes were ignored to provide a sterile environment. The results of the virtual experiments provide deep insights into the importance of selecting the right CITs. Future opportunities of extending the research are analyzing the CITs that fall between the ends of the bands analyzed in this research. Some of the technologies that come to mind are message boards, Wikis, instant messengers, and video conferencing.

CONCLUSION

Project costs and on time completion are two of the most important project metrics tracked by project managers. We showed that the choice of CITs in a communication plan can affect the total project communication cost and the time taken to complete the project. As well, we found that there are tradeoffs between the total communication cost and schedule performance and the tradeoffs differ depending on the CIT type. Project managers need to realize these tradeoffs when selecting the CITs for the project. In particular, our research showed that total communication costs were different for projects with different complexities and communication plans and that the synchronous CITs were the cheapest option to implement. Moreover, communication plans calling for only synchronous CITs resulted in less risk and lower overall communications costs. Thus, project managers might realize benefits from prescribing synchronous CITs.

Asynchronous CITs require more messages to communicate the same amounts of information content than via synchronous CITs. However, while communication plans using only asynchronous CITs resulted in delayed projects that were behind schedule, there was less variation in project schedule completion. As such, the manager may better estimate when the project will actually complete based on the communication plan. Hence, it is important for the project managers to think strategically about the communication costs and time required to communicate due to project complexities and CITs, and factor these tradeoffs into the communication plan.

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APPENDIX

The attributes in the table below are listed in the precedence order in which they are initialized in the simulation. That is, while running the simulation, these attributes are determined based on the values given to previous attributes. All values, however, are from the range listed in the range column.

Attribute	**Range**
Project cost	(1, 25)
Technical Objective	(1, 50)
Organizational capability	(0, 5)
Information content requirement	(1000, 35000)
Project complexity	(1, 9)
(experimental condition) Low project complexity	(1 ,3)
(experimental condition) Medium project complexity	(4, 6)
(experimental condition) High project complexity	(7, 9)
Estimate project schedule (weeks)	(17, 102)
Functional expertise	(0, 5)
Information content per Message	(1, 8)
Message Complexity	(0, 5)
Message Relevance	(0, 5)
Message Duration (minutes)	(1, 120)
Media selection (CIT type)	Synchronous/Asynchronous